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Fast Brownian Dynamics of Nanoparticles Observed in Liquid Phase Scanning Transmission Electron Microscopy

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Liquid phase transmission electron microscopy (LPTEM) allows investigating nanoparticle nucleation, growth and dynamics with high spatial and temporal resolution [1]. However, the nanoparticles near the solid-liquid interface in the LPTEM show different dynamics, specifically, 3-7 orders of magnitude smaller diffusion coefficients were typically reported compared to that of Brownian motion in bulk water [2]. The mechanisms behind the anomalously slow motion are not yet clear [3,4]. The nanoparticle dynamics can be dominated by the electron beam modified solid-liquid interface at the encapsulating silicon nitride membrane (Fig 1a), and given the unknown cause of the radically modified behavior, this could raise concerns of how much results on particles on the membranes can be generally trusted as representing ex-situ results.

Therefore, in this study, we studied Brownian motion of Au nanoparticles freely moving in the LPTEM in STEM mode as shown in Fig. 1a and b, and measured the translational diffusion coefficient using single particle tracking. For the first time, we report a diffusion coefficient matching that of free Brownian motion (Fig 1c and d), which establishes LPTEM in STEM mode as a reliable tool with high spatiotemporal resolution for measuring dynamics of nanoparticles in their native environment.

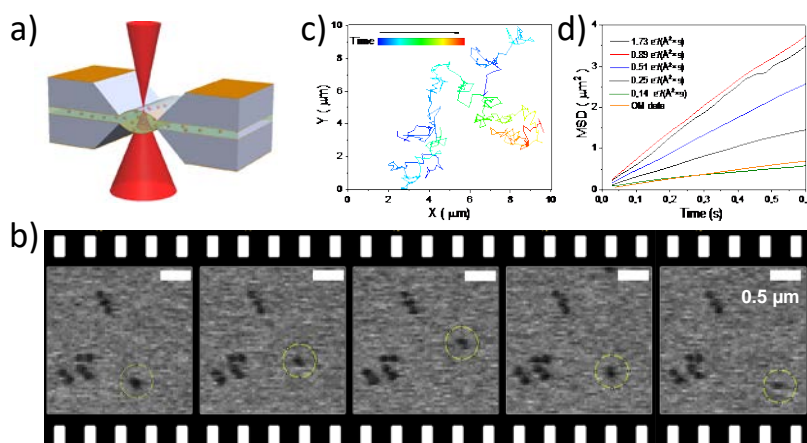


Figure 1: a) Schematic view of STEM imaging in a LPTEM; b) STEM image sequence of freely moving nanoparticles at electron flux $0.51 \text{ e}^-/(\text{\AA}^2 \times \text{s})$, in 70 wt% Glycerol/water solution. Frame interval time is 30 ms. For illustration purpose, the moving nanoparticles are marked with circle line; c) Trajectories of three randomly selected Au particles at the electron flux $0.51 \text{ e}^-/(\text{\AA}^2 \times \text{s})$. Time interval is 30ms; d) Mean square displacement (MSD) vs. Δt .

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